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Alternative energy resources in Bangladesh and future prospect

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ABSTRACT

Present energy scenario, alternative energy resources and future prospect in Bangladesh have been reviewed comprehensively and presented in this paper. This work compiles latest literatures in terms of thesis, journal articles, conference proceedings, web materials, reports, books, handbooks on energy and renewable energy resources in Bangladesh. Deficiency in the energy sector is a major problem in Bangladesh, which hinders the smooth economic development workflows. Being the eighth most populated country in the world, Bangladesh is one of the most electricity deprived nations with a total electricity generation of only 5000 MW. Thus, Bangladesh is facing difficulty to achieve an overall sustained progress in the economy due to the lack of a sound energy security. In this context, alternatives of conventional energy sources, renewable energy resources can be the sustainable solution for the energy security. This study has discovered the factors that are useful to lessen the existing power supply crisis and summarized the current energy scenario, lack of infrastructure and conventional energy sources to promote the renewable energy sources to fulfill the power demand in Bangladesh.

Contents

1. Introduction

Energy is the vital requirement in industrialization for achieving or ensuring technological improvement, sustainable growth of economy, mechanization and transformation through the industrialized sector all over the world [1–3]. As a developing country like Bangladesh it is the most challenging vision to be become sovereign in power generations. However, the continued energy demand and consumption are rising fast globally because of which the scientists are distressed that how to meet and materialize the increasing shortage of energy in the future for wellness of the global people [4–5]. It is projected that the global energy demand may be raised up to 33% by 2030. It is also observed that the global energy consumption will be accelerated up to 45 billion MW in the year 2007, whereas further demand has been estimated up to 218 billion with

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Nomenclature

BBS	Bangladesh Bureau of Statistics
BERC	Bangladesh Energy Regulatory Commission
BP	Bangladesh Plan
BPDB	Bangladesh Power Development Board
BPRE	Bangladesh Policy of Renewable Energy
BRAC	Bangladesh Rural Advancement Committee
BUET	Bangladesh University of Engineering Technology
CDM	Clean Development Mechanism
DC	Direct Current
GDP	Gross Domestic Product
GOB	Government of the People's Republic of Bangladesh
ICT	Information and Communication Technology
LGED	Local Government Engineering Department
MOF	Ministry of Finance
MDG	Millennium Development Goals
MPEMR	Ministry of Power, Energy and Mineral Resources
NEP	National Energy Policy
NGOs	Non-Government Organizations
PV	Photovoltaic
RE	Renewable Energy
REB	Rural Electrification Board
R&D	Research and Development
RETs	Renewable Energy Technologies
RSF	Research Support Facility
SRE	Sustainable Rural Energy
SREF	Small Renewable Energy Programme
SHSs	Solar Home Systems
SEDA	Sustainable Energy Development Agency

Subscript

Ktons	kilotons
sq km	square kilometer
%	percentage
mm	millimeter
m/s	meter per second
°C	degrees celsius
°F	degrees fahrenheit
MJ/m^2	megajoule per meter square
GWh	giga watt hour
kWh/m^2	kilowatt hour per meter square
kWp	kilowatt peak
MWp	megawatt peak
kW	kilowatt
MW	megawatt
kWh/m^2/yr	kilowatt hour per meter square per year
H	efficiency
w/m^2	watt per meter square

an increase rate of 49% by 2035 [6]. However, people of this country are still fighting in order to obtain energy security with other basic needs. Bangladesh is the most densely populated country of the world where 1099 people live in a square kilometer according to the recent national statistics [7]. It is one of the least urbanized states in the world in which 72% of people reside in the countryside. Regrettably, still its per-capita GDP (gross domestic product) is one of the lowest in the world which is US$ 848 in 2012 and GPD growth per annum is 6.3% as shown in Figs. 1 and 2 [7–9]. According to economic indicators, the minimum required per capita income is US$ 1300 to manage the meaningful growth rate of 7–8% that may make the country one of the middle-income nations by 2020 [7]. Energy, more clearly electricity (i.e. power generation), is the precondition for the sustainable development of a country (i.e. technological development and economic growth) and for making it a middle-income nation (Fig. 3) of the world. It is comprehended that the future economic growth and economic development are expected to meet the rapid energy demand by overwhelming deficiency and additional constrains.

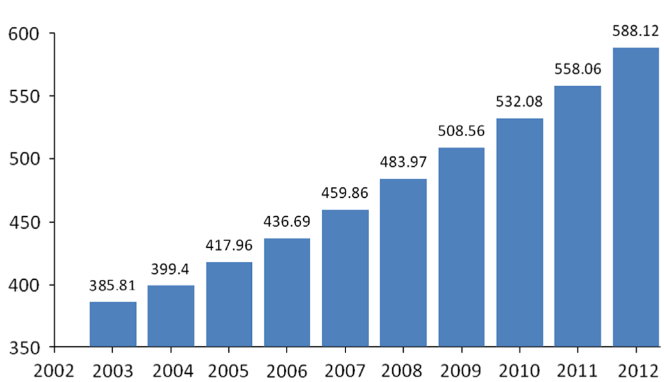


Fig. 1. Bangladesh GDP/Captia in US Dollar (constant price since 2000).

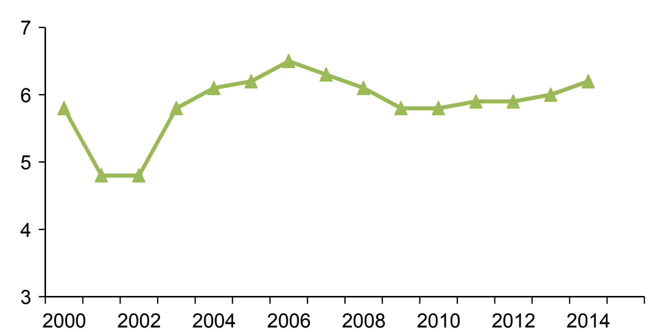


Fig. 2. GDP growth in Bangladesh.

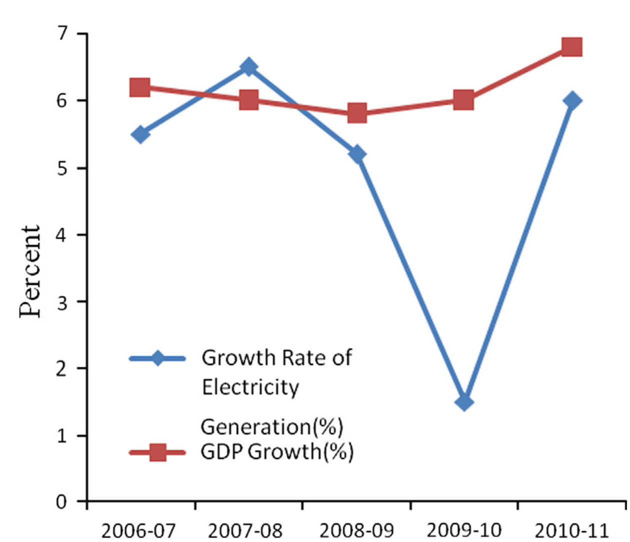


Fig. 3. Relationship between GDP and electricity generation growth [15].

Bangladesh currently has been passing with a critical issue that is insufficiency in energy production, distribution and dissemination with respect to the development requirements. Energy consumption is an important quantitative measure that provides a rough estimation to the level of progress achieved within a civilization and industrial activities in a nation. However, with its 160 million people, Bangladesh could not ensure yet 100% accessibility of power supply [7]. Only 20% people are now grid-connected [10] and only 42% people are connected with electricity [11]. Per capita electricity consumption is only 146.5 kWh, whereas in India is 480.5 kWh and in Pakistan is 456.2 kWh [12]. The current literature indicates that for the developed countries, the average per capita electricity consumption is 8009.5 kWh but for the developing countries consumption is 1169 kWh. In addition, for any high-income country, the average per capita electricity consumption is 9789 kWh and for any low-income country, it is 392.4 kWh [12]. Thus, in every single index Bangladesh is far behind because of poor electricity generation, consumption and dissemination.

However, by introducing the potentials of renewable energies like solar, wind, biomass and biogas, geothermal, sea wave, lightning, and hydro, Bangladesh can meet the required energy demand which may confine and ensure the electricity accessibility and enhance the energy security for the future development. The renewable-energy technologies (RETs) recently became the multi-billion-dollar industry, and most of the prominent petroleum companies started business with renewable energies [13]. Thus, as a developing country Bangladesh has a great prospect if it can introduce the technology on renewable energy in the national level that may result in self-reliant energy production with positive outcomes. Recently renewable energy and related technology have been introduced on a very small scale in the rural areas that made a positive change of the daily life, although it is not so extended in terms of requirements. Unfortunately, the rural people live under poverty and their daily income is below US$1 that cannot lead them to afford the cost of the renewable energy like solar power. On the other hand, Bangladesh has a minimal reserve of natural resources (like natural gas and coal) which is supposed to be used for energy production, but it is shocking that the gross reserve is 15.32 TCF [12] that may end by 2015–2020.

It is understood from the national power demand and statistics that the present energy demand is 7% per annum, and within the current power generation capacity (i.e. 5000 MW), it is impossible to fulfill the national demand for sustained economic growth [10,11,14,15]. Therefore, it is mandatory to promote our power sector in order to ensure the development of this country. The proper assimilation of renewable-energy technologies (RETs) in the power sector through national energy planning would be, therefore, the right trend for energy security. In this context, renewable energy would be a viable option to achieve energy security in Bangladesh. Hence it should boost up the renewable-energy sector with proper investment and appropriate policy; only then Bangladesh could possibly get energy security from now onwards, and be able to eradicate the power-generation problems in a sustainable way.

Therefore, this study has taken an initiative with an analytical justification to figure out the factors that are useful to lessen the existing power supply problem and has summarized the current energy scenario, lack of infrastructure and conventional energy sources to promote the renewable-energy sources. This research study aims to produce a guideline for both the policymakers in the government and private levels. This study also focuses the policy gaps for sustainable renewable energy how to ensure the accessibility of electricity for mass people. Hence, current study framework has tried to indicate that how the abundance production of renewable energy can reflect its potentiality to the economic growth, sustainable development, technological improvement, and socio-economic development [16]. It is obvious that Bangladesh has economic, political and financial constraints, and limited capacity to afford high technology which would be expensive, but the advocacy and proposal by this study would help to make a balance between conventional energy supply and renewable-energy demand; so that decision maker can merge a stable and applicable energy policy [17]. Finally, this study will be the witnessed to support alternative energy context and advocate why the conventional power system needs to be redesigned in the way forward for Bangladesh.

This study is shaped as follows: Firstly, a geographical status of Bangladesh is focused in Section 2. Secondly, a short outline of energy situation of Bangladesh has been described in Sections 3 and 4. It is followed by a brief assessment of foremost renewable energy resources accessible in the country in Section 5. Section 6 shows the existing and approaching projects of renewable energy for power generation. Finally, Section 7 shows the possible economic growth and development by the implementation of renewable energy.

2. Geographic profile of Bangladesh

Bangladesh is located in the north-eastern part of south Asia and splits its longest three geographical borders (4000 km) with the nearest country India with a 24° 0′ 0″ N latitude in the north (N) and 90° 0′ 0″ E longitude to the east (E). Myanmar is the extreme southeast, and the Bay of Bengal is the southern margin Fig. 4. Geographically, it is mostly covered by a low-lying land delta by the river zone of Brahmaputra and Ganges and has occupied a land of 147,570 sq km. Bangladesh is known as one of the world's largest populated countries (i.e. 162.20 million in 2011) where 1099 people live in a square kilometer [7]. The floodplain zones are covered by 80% of the country's inland areas and the mean altitude ranges from 0.8 m in the coastal zones. However, the north-east basin zones from the sea level can be found up to 3–6 m in their mean altitude, and some southeast and northeast zones are over 1000 m [7]. Bangladesh stands at the Gangetic delta that typically has an uneven climate belonging to humid monsoon, warm and wet during the summer and dry in the winter season. The lowest average temperature that belongs to January is about 10–15 °C, and the highest average temperature is about 33–41 °C between April and July. The typical weather is mostly humid where the rainfall varies annually from 1525 mm (60 in.) to 5080 mm (200 in.) in different locations. The country receives the highest rainfall during June–September whereas little rainfall is predicted in the winter season, and experiences relatively high temperature and humidity with a great variation in rainfall as a sub-tropical zone [18].

3. Present scenario of energy sector in Bangladesh

The power generation in Bangladesh mainly depends on natural gas and currently about 79% of electricity is produced from natural gas and coal. However, some researches indicated that the net reserve of gas (i.e. probable) that remains is only 15.32 TCF [14] and the coal reserve is only 2.7 billion tons [19]. According to Sharif [15], the existing conventional gas reserve is expected to be exhausted by 2020. This study understands from the literature and national reports that the average power generation growth rate is only 316 MW per year, which is much lower than the growing power demand [14–15,18–19]. The national prediction estimated that the typical energy demand is supposed to be raised up to 7500 MW from the existing level by the year 2015. Therefore, it is sort of a nightmare to accelerate the power generation up



Fig. 4. The geographical map of Bangladesh.

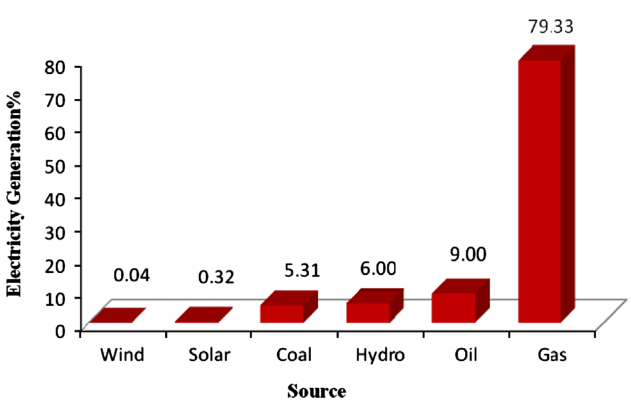


Fig. 5. Percentage of electricity generation in Bangladesh from different sources, 2006 [21].

Table 1
Present energy scenario in Bangladesh, as of FY 2011 [15].

Sector	Status
Electricity growth	10% in FY 2010 (Av.7% since 1990)
Total consumer	12 Million
Per capita generation	236 kWh
Present generation capacity	5936 MW
Present demand	6000 MW
Present available generation	4000–4600 MW
Maximum load shedding in FY 2010	1500 MW (Hot summer)
Future demand FY 2015	15000 MW
Future demand crisis FY 2015	11500 MW

to 11,500 MW by 2015 [20]. The graph in Fig. 5 and Table 1 indicate the standard electricity generation in Bangladesh from assorted resources. In addition, recently the power crisis (load shedding)

Table 2
Installed capacity and maximum power generation in Bangladesh [15].

Fiscal year	Installed capacity (MW)	Growth rate (%)	Maximum generation (MW)	Growth rate (%)
2000–01	4005	–	3033	–
2001–02	4230	5.62	3218	6.10
2002–03	4710	11.35	3458	7.46
2003–04	4710	0	3622	4.74
2004–05	5025	6.69	3751	3.56
2005–06	5275	4.98	3812	1.63
2006–07	5262	−0.25	3718	−2.47
2007–08	5262	0	4130	11.08
2008–09	5803	10.28	4162	0.77
2009–10	5978	3.02	4606	10.67
2010–11	6658	11.38	4699	2.02

has been increased up to 950 MW in an average and the crisis growth rate is 35 MW in average per annum since 2007. The current crisis scenario suggests that the future average load shedding may be raised up to 900 MW per year until 2015 [14–15,18–19].

Furthermore, the growing pace of energy production is about 5.37% that is lower than the existing requirement which is about 5.43–6.72% per year during the identical phase [14–15,18–19]. Interestingly, the statement from Power Development Board (PDB) of Bangladesh and power demand does not reflect the real scenario on the energy demand. Therefore, the time has come to rethink of adequate investment in power industry and development of an effective infrastructure as an alternative energy source in this regard. It should be accounted into consideration that only 6.36% of power and energy belongs to renewable sources such as by solar, hydro and wind, and 93.64% of power and electricity is produced from fossil fuels like gas, coal and oil in Bangladesh [15,18,19,21]. As this study notes, Bangladesh is far behind to fulfill the national energy and power demand for electricity generation, consumption and dissemination. Therefore, alternative energy options must be brought into key consideration and constraints of alternative energy sources must be eliminated in the days to come to ensure the accessibility of sound power supply for economic development.

4. Energy consumption and demand

According to energy consumption and demand, the household consumption outline of energy increased from a declining rate from 2001 to 2002 (i.e. except 2005–2006) until recently. The commercial sources also show similar trends [7]. The uses of system energy in the manufacturing services from 2005 to 2006 also have increased after having a falling rate in the year 2003–04. The national data and statistics from the year 2000–2001 to 2007–2008 show that energy consumption and demand were the highest during the year 2005–06 and the rate of annual increase was about 15.6% in the commercial services, 13.8% for the households, 13.3% in the manufacturing services and 6.4% was in the rest of the services [7]. Table 2 and Fig. 6 (a) and (b) present the electricity consumption by category and their attached growth rate in Bangladesh. The statistics of Fig. 6 (a) and (b) indicate that the typical energy demand and consumption are increasing in a regular fashion (i.e. demand was 3970 MW in 2007 and 4833 MW in 2011) but the acceleration to meet the required power generation is very little as the growing crisis rate (load shedding) on average is 35 MW per annum since 2007. Therefore, considering the constraints and limitations of conventional energy demand, supply, and production; it is a very critical challenge to meet the further national demand of 11,500 MW by the year 2015 [15].

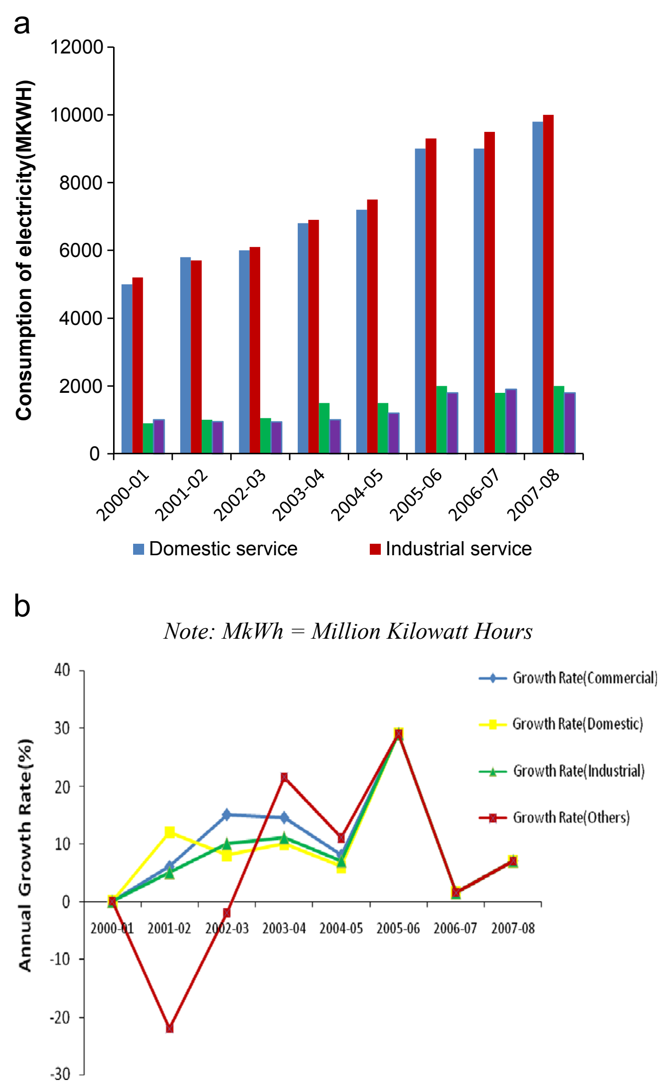


Fig. 6. (a) Electricity consumption by category (MkWh) from 2000 to 2008. (b) Electricity consumption category by growth rate (%) 2000–2008.

5. Leading renewable energy sector in Bangladesh

Bangladesh is blessed with the abundant sources of renewable energy. The required energy demand on power generation can be fulfilled by utilizing unconstrained renewable sources [22]. It is a fortune that gradually more energy production from renewable resources and its diverse technologies are becoming affordable, economically feasible and capable to race against fossil-fuelled technologies in the near future [21]. As the energy consumption

and demand are a real concern in Bangladesh, the extent and prospect of the renewable resources like solar power, wind energy, hydro power, biogas and biomass are necessary to be correctly spread in Bangladesh (Fig. 7). This study recognizes that high investment cost of renewable technologies may be one of the limitations but in the very long run there are not much more alternatives [23]. The recent scenario, preference and improvement of the major renewable sources in Bangladesh are as follows.

5.1. Solar energy

Bangladesh could possibly meet its unprecedented energy demand as well as increasing energy security through their progression by acknowledging the potential of solar-energy resources. Therefore, as an alternative of present energy crisis scenario, solar energy such as solar photovoltaic (PV) can resolve a portion of power demand with accompanying deficiency and problems. Bangladesh is positioned between 24° 0' 0″ N latitude and 90° 0' 0″ E longitude, which is an ideal position for preserving solar power [24,25]. The unit price of PV, manufacturing and installation cost have been decreasing over the years, and that is the advantage for investment as an economic scale for a developing country like Bangladesh [26]. Recent literatures on solar photovoltaic (PV) suggest that the daily average variation of solar discharge fluctuates following the pattern of dry and wet seasons in Bangladesh from 4 to 6.5 kWh in a square meter [25–27]. The highest level of radiation is accessible from March to April whereas the least from December to January and the average sunlight hours vary between 6.69/7.6 h, 6.16 h and 4.81 h respectively in winter, summer and monsoon seasons [27]. The average solar radiation in six divisions has been outlined in Fig. 8 [21].

The figure represents that the projected value of solar radiation is the highest in the month of March–May, where 1 (one) square meter area occupies the potential of producing 4–5 kWh/m^2/day [29]. The maximum sunlight hours recorded in Khulna differ from 2.86 to 9.04 h whereas in Barisal it varies from 2.65 to 8.75 h [27,29]. Therefore, Bangladesh has a great prospect to use solar energy not only as a direct production system but also as the accessible infrastructure together with combined cycle power station. There are some NGO's such as IDCOL, Grameen Shakti, Rahimafroz and Energypac which are promoting the solar technology for power generation. Infrastructure Development Company limited (IDCOL) followed by RSF, BRAC and Srizony Bangladesh has contributed the maximum effort by installing 1,320,965 solar home systems (SHSs) with a capacity of 36.5 MW until January 2012 [30]. The number of installation of solar plant in Bangladesh is impressive considering the growing development as such by (a) Dhaka 346,161, (b) Chittagong 257,578, (c) Barisal, (d) Rajshahi 185,267, (e) Khulna 146,388 and Sylhet 140,386 units but installed capacity is very little compared to the national power demand [30–31].

Currently, the cost of PV technology is a vital question to afford for a least developing country like Bangladesh [24], even though geographical position is ideal for preserving solar power and the technology of PV is extremely capable to switch daylight into electricity [21]. We comprehend from the literature that Bangladesh can be very prospective for generating solar energy in the near future for its geographical location. Even solar thermal power plant can be introduced to the northern provinces of Bangladesh where the solar intensity is very high [32]. Therefore, as the issue is concerned for the long-run policy issues, appropriate integration of action plans, national budget, subsidy issues and national energy planning would be understood to eliminate the policy gaps.

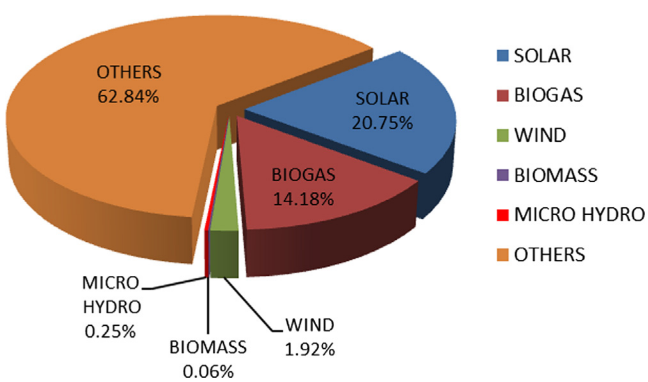


Fig. 7. Ratio of different renewable energy sources in Bangladesh [21].

5.2. Wind power

The technology of wind energy is to exchange the airflow into motorized force, which is ultimately transformed into electricity. Bangladesh occupies huge highlands and islands in the Bay of Bengal and 724 km long coastlines, which may bring enormous potentials for power generation from wind energy, especially in the monsoon seasons as strong south and southwesterly monsoon air usually flows from the Indian Ocean over the Bay of Bengal and enters over the coastal regions [33]. These winds propel from March to September where its monthly average speed is 3–6 m/s. It is observed that the wind rapidity accelerates once it enters the V-shaped coastlines of the country. In recent the improvement of wind rotor aerodynamics made it easy to extract power even from lower wind speed of 2.5 m/s [34]. According to research studies by BUET, BCAS, LGED and meteorological department, winds are

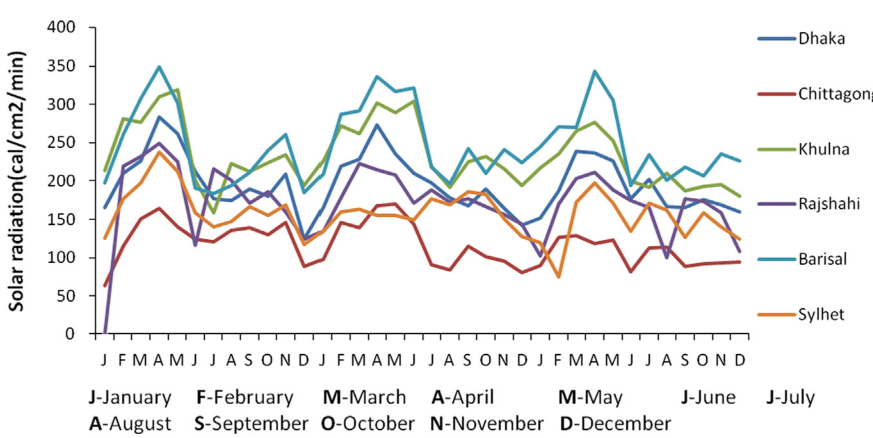


Fig. 8. Average solar radiation in the six divisions in Bangladesh [28].

obtainable in Bangladesh generally during the monsoon and sometimes couple of months before or after the monsoon [33,34]. Bangladesh Centre for Advanced Studies initiated one-year data, which focused on 50 m height's turbines in the coastal regions which differ by the wind force that varies between 4.1 and 5.8 m/s whereas the energy density is about 100–250 w/per m^2 [31].

Power generation from coastal wind can be transferred to different areas throughout the country through the high voltage transmitted connections. There are lots of the economic aspects as operation and maintenance cost is very little throughout the full lifespan of wind turbines [35]. Therefore, the deficiency of energy power might be compensated with the help of wind power plants along the coastal regions. As the wind force alongside the Bay of Bengal is relatively higher, the wind turbines such as from Kuakata, Sandwip and St. Martin islands can be considered as the prospective areas for wind energy power [36]. It is apparent that many people on these islands are fishermen and unable to get access to the electricity from the national grid. Therefore, wind energy in the coastal areas can be an efficient solution of power energy and electricity generation as there is a sound advantage to set up wind turbines and develop wind energy in the coastal regions [37]. To verify the potentiality of renewable sources for power generation, small-scale wind turbines can be set up in the regions (Table 3) like St. Martins Island, Patenga, Bhola, Barguna, Dinajpur, Thakurgaon and Panchagar [38]. However, some wind-energy power sources from different institutions are available in Bangladesh, but their contribution to the national grid is negligible (Table 4). Therefore, government intervention is greatly required in this regard.

Table 3
The feasibility of wind conditions at different places in Bangladesh [34].

Site	Reference height (m)	Annual average wind speed (m/s)
Teknaf	5	2.16
Cox's bazar	10	2.42
Patenga airport	5	2.45
Kutubdia Island	6	2.09
Sandip Island	5	2.16
Hatia Island	6	2.08
Bhola Island	7	2.44
Khepupara	10	2.36

5.3. Biomass and biogas

Biomass can be considered to be the largest energy source in Bangladesh. About 70% energy consumption of its total production is being supplied by the elemental energy for cookery and warming of pastoral household. Biomass consists of varieties of natural and organic substances from fuel wood to aquatic foliage. There are many existing technologies available for biomass energy translation into electrical and heat energy. There are two types of extensive technologies available, which are the direct ignition and gasification. The straight ignition process occupies the corrosion of biomass with surplus air, creating warm chimney gases that result in generating steam, which is finally, applied for power generation [34]. In contrast, gasification rivets biomass conversion producing a low and low medium calorific gas and then the obtained gas is utilized in combined-cycle power to fuel generating plants. It is recognized from the literatures that up to 40% electrical translation efficiencies are achievable as about 30 MW in a short period [39].

Table 4
Wind turbine installations in Bangladesh by different organizations [34].

Organizations	Type of application	Installed capacity (Watt)	Location	Present status
Grameen Shakti	3 Hybrid	4500	Grameen offices in the coastal region	Functioning
	Hybrid	7500	Cyclone shelter in the coastal region	Functioning
BRAC	Stand-alone	900	Coastal region	Functioning
	Hybrid	4320	Coastal region	Functioning
Bangladesh Army	Stand-alone	400	Chittagong hill Tracts	Functioning
IFDR	Stand-alone	1,100	Teknaf	Functioning
	Stand-alone	600	Meghnaghat	Functioning
LGED	Hybrid	400	Kuakata	Functioning
	Total	19,720		

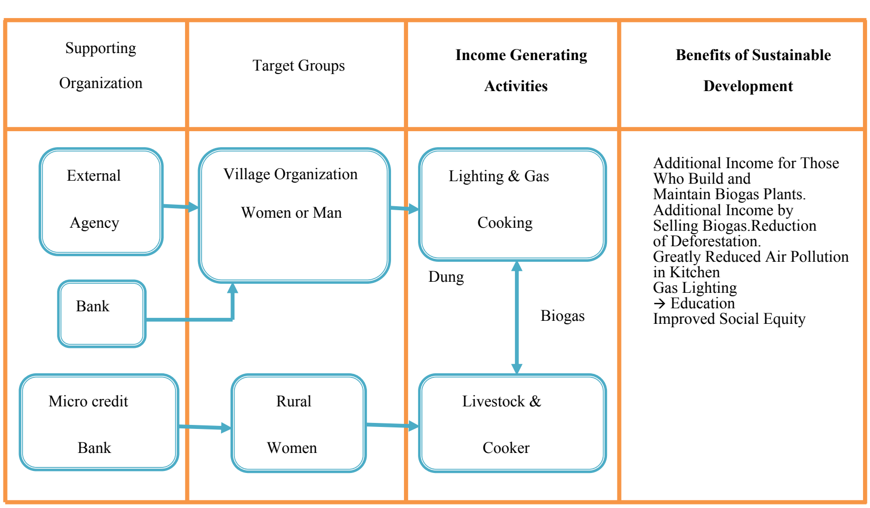


Fig. 9. Biogas consumption in Bangladesh under NDBMP [42].

Various feedstocks such as organic domestic waste, manufacturing waste, fertilizer, sludge, and others have been demonstrated and pertained commercially by the anaerobic digestion of biomass (Fig. 9). Bio-gas comprises of 40–70% of CH4, 30–60% of CO_2 and 1–5% other gases, which are generated from creature compost and poultry fertilizer in specific bio-digesters. Therefore, produced gas is burnable as well as usable for the generation of electricity [40].

Bangladesh is a country where its main agricultural production is rice and average production is about 35,000,000 MT per year. If 20% of the produced rice (i.e. 7000,000 MT) could be turned useful for biomass, then the biomass power generation from rice husk can be more imperative. In addition, Bangladesh is an agro-based country which produces a variety of waste products that can be turned into biogas energy which is economically profitable and may support to overcome the national power crisis. Moreover, a total of 436 tons recyclable industrial waste is managed everyday in Bangladesh. Furthermore, per day 3054 tons wastes is projected to obtain by 2015 and collective dumping capacity is expected to 9 million tons by the end of 2015 [41]. The technology option to convert waste to energy might be an alternative option to support power at the national level. Though some of the rural people are using a small scale of electricity derived from their livestock's wastes for daily household work, government should focus on the issues and it should be commercialized connecting to the national grid where still no electricity is available in the rural areas. However, there are some biogases and biomass energy power sources from different institutions available in Bangladesh, but their input to the national level is insignificant (Table 5). Therefore, government intervention is also greatly required in this regard as the rural power source is a concern.

Table 5
Estimates of energy supplied by traditional biomass fuels [37].

('000 tons of coal equivalent)				
Fuels	2000–01	2001–02	2002–03	2003–04
Cow-dung	2471	2471	2471	2505
Jute stick	966	1010	966	922
Rice straw	1429	1409	1418	1218
Rice hulls	2810	2854	2898	2854
Bagasse	3–10	366	366	392
Fire wood	1166	1219	1219	1272
Twigs and leaves	1378	1471	1484	1537
Other wastes	1230	1273	11317	1361
Total	11790	12033	12139	12258

5.4. Hydro energy

Hydropower is another kind of alternative energy that requires both water current and height to generate functional power. The system of this achievable energy is considered as conservation and absorption energy in the outline of automatic stream energy [43]. Micro-hydro power is capable to produce up to 5–300 kW of electricity [44]. This is one of the simplest technologies, which transfers hydropower to mechanical power energy. The developing country like Bangladesh is very much suitable for Micro-Hydro technology and the cheapest technology as well. Many canals and branches of the rivers in Karnafuli, Shangu, Matamuhuri are supposed to be good prospects for installing micro-hydro power along with the Chittagong Hill Tracts [45]. Recently, the first micro-hydro power unit at Bamerchara, Chittagong, has been established by the Sustainable Rural Energy (SRE) under LGED. However, only about 4 kw of electricity can be produced because of insufficient water current [46–47]. In 1981, Bangladesh Water Development Board (BWDB) and Bangladesh Power Development Board (BPDB) in the year of 1981 explored potential sites, which are suitable for micro-hydro power generations, which are listed in Table 6 [24]. Sustainable Rural Energy (SRE) has also discovered some possible locations for micro-hydro sites in Chittagong areas in 2004, which are listed in Table 7 [48]. From Tables 2 and 3 and the related discussions, it is clear that there is immense option of generating electricity from the micro-hydro energy. However, unfortunately, Bangladesh has been unable to generate power energy from the hydro energy.

6. Other prospective renewable energy sources

They are many other renewable resources like bio-diesel, oceanic wave, tidal power and geothermal energy to generate electricity except solar, wind, hydro, biomass and biogas energy for the future alternative energy sources in Bangladesh. Although these are expensive technologies, international and local scientists are trying their best to make it viable as the most alternative option so as to remove the energy crisis in Bangladesh. Bangladesh is a semi-tropical country which is most suitable for growing various species of algae in abundance that can be helpful to extract

Table 6
Potential small hydro sites identified by BPDB and BWDB in Bangladesh [24].

District	River/Chara/Stream	Potential of electrical energy ("kW")
Chittagong	Foy's lake	4
Chittagong	Choto Kumira	15
Chittagong	Hinguli Chara	12
Chittagong hill Track	Sealock	81
Chittagong	Lungichara	10
Chittagong	Budiachara	10
Sylhet	Nikhari Chara	26
Sylhet	Madhab Chara1500ft. from fall	78
Sylhet	Rangapani Gung	616
Jamalpur	Bhugai-Kongsa at 2 miles U/S of Nalitabari P.S	69 kW for 10 months 48 kW for 2 months
Jamalpur	Marisi at Dukabad near Jhinaigati Thana Head quarter	35 kW for 10 months 20 kW for 2 months
Dinajpur	Dahuk at Burabari	24
Dinajpur	Chawai at U/S of Chawai L.L.P	32
Dinajpur	Talam at U/S of Talam L.L.P	24
Dinajpur	Pathraj at Fulbari	32
Dinajpur	Tangon at D/S of Nargun L.L.P	48
Dinajpur	Punarbhaba at Singraban	11
Rangpur	BuriKhoraChikli at Nizbari	32
Rangpur	Fulkumar at Raiganj Bazar	48

Table 7
Micro hydro power sites identified by SRE Study in Bangladesh in year 2004. [48].

Site	Expected power generation (kW)	Socio-economic infrastructure within 1 Km		
		House hold	School/Mosque/Bazaar/Clinic	Small industry
Nunchari Tholipara, Khagrachari	3	100	3	1
Chang-oo- Para, Bandarban	30	200	5	2
Bangchari, Bandarban	25	600	12	5
Liragaon, Bandarban	20	500	8	3
Kamalchar, Rangamati	20	150	8	9
ThangKhrue, Rangamati	30	300	6	3
Monjaipara, Bandarban	7.5	50	3	–

biodiesel from it. Oceanic wave and tides of the storms also can be other potentials for renewable energy as Bangladesh is most cyclone-prone country. Almost every year two or three cyclones hit in the Bay of Bengal which can be used by specific technology for power generation. Besides, the geothermal method for generating energy is very potential which is supposed to produce prospective volume of electricity but its technology is still quite expensive in the perspective of Bangladesh.

The renewable energy policy was first drafted and released in Bangladesh in the year 2002. The policy outlined included mechanism, modalities, fiscal, tariff regulations, and other related matters. Unfortunately, these policy outlines still do not confirm and employ an action plan for possible future energy solution [49]. The Ministry of Power, Energy and Mineral Resource of Bangladesh (REDA) is only the influential administer for rural electrification and implantation on renewable energy. Though the REDA was projected to institutionalize in 2002, the government of Bangladesh has determined to set up another autonomous division that is Sustainable Energy Development Authority (SEDA) to promote power generation from renewable resources [50]. In addition, Infrastructure Development Company Limited (IDCOL) was begun in 1997, as a nationalized non-banking economic organization administering economic issues to enhance rural energy and renewable energy expansion projects (i.e. solar home system, biogas) with 15 participating national non-government organizations [47].

The projected production per unit of renewable energy based installed capacity is far fewer than conventional power plants. Thus, installed capacity of renewable energy based power should be at least 1000–1200 MW in order to attain a dependable generation of 800 MW. However, Bangladesh is still far behind than its expected growth of renewable energy (i.e. target 1000–1200 MW) to ensure the electrification for all. Sustainable Energy Development Authority (SEDA) has been accelerated in order to promote the renewable energy from the conventional sources. According to the accepted renewable energy policy 10% of the total energy production about 1600 MW would be added by 2020 from renewable sources and 5% of the total generation 450 MW would be added by 2015 [46]. The required area to produce 100 MW of energy with an annual average direct normal irradiance (DNI) of 2000 kWh/m^2 is about 2 km^2. It is sufficient to operate an absorbed solar power (CSP) plant as Bangladesh receives an annual average DNI of almost 1900 kWh/m^2 [50,51]. To ensure sustainable development in the energy sector, Bangladesh has set a target on March 14, 2011, to generate 500 MW of electricity establishing solar home systems [50–52]. It is also planning to set up solar irrigation system to reduce the diesel cost. In addition, BPDB is planning to extend the Karnaphuli hydro power plant to generate 100 MW additional electricity which will be effective to operate recently [53].

7. Conclusion

Energy crisis and possible alternative energy sources are really big issues in Bangladesh. Renewable energy is one of the sustainable solutions to avoid the power crisis. To find out the factors of exiting power supply problem, current energy scenario, lack of infrastructure on conventional energy sources promote the renewable energy option. It needs to take visionary planning, must attract investment and create mass awareness. The potentiality of renewable energy resources is very good for its national growth, sustainability and socio-economic development. The use of renewable energy in the national energy context will develop the sustainability and socio-economic development in Bangladesh.

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